Volume 8G, Number 4, December 1959

BULLETIN OF THE RESEARCH COUNCIL OF ISRAEL

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GEO-SCIENCES

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DESCRIPTIVE ANALYSIS OF A TYPICAL UPLAND REDEARTH OCCURRING IN THE SHAN PLATEAU OF EASTERN BURMA

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ABSTRACT

A basic characterization of a typical lateritic upland red-earth was attempted.

Its chief physical attributes are: favourable structure and structural stability, great depth, low swelling, easy workability, free drainage and generally satisfactory moisture relations.

Its chief drawbacks are its pronounced acidity, low organic matter and nutrient content, and tendency to extreme leaching of soluble components.

It is considered that with proper cultural practices, soil amendments, organic and mineral fertilizers, — the soil can be made productive. Permanent agriculture could then replace the present practice of shifting cultivation.

I. INTRODUCTION

The Shan region of eastern Burma is a fairly uniform plateau, primarily of limestone and dolomite strata of considerable age. For the most part, elevation varies between 600 and 1300 metres above sea level. The topography varies from relatively flat to steep, though it is more often of the undulating or rolling type.

The climate is characterized by three distinct seasons: summer (June to October) is warm and humid; winter (November to February) is cool and dry; and spring (March to May) is warm and dry. Average temperatures measured in the northern Shan are: for July 28°C; for January 15°C. The prevailing monsoon-type rainfall is in the order of 1250 to 1750 mm.

The soils of the sloping uplands are of the red-earths type. Those of the river valleys are alluvial and often poorly drained. The soils of the plains sometimes show an extreme degree of laterization and may contain horizons of concretionary or even of totally consolidated ironstone. Where such an impenetrable pan occurs, tree growth is inhibited and a savannah-like grassland vegetation predominates.

The natural vegetation of the uplands is a dense forest of subtropical broad-leaf hardwoods. In vast areas the virgin forest has largely been destroyed by timber extraction and more particularly by the prevalent practice of burning and clearing patches for temporary, or shifting cultivation ("taungya"). When such patches are abandoned, they are soon reinvaded, —grasses, shrubs, bamboos and finally trees appearing in succession. The better lands are seldom allowed to revert entirely to their original forest cover, and are cleared repeatedly at 10 to 15 year intervals. Local cultivators are compelled to abandon their patches after only three or four

years of continuous cropping, since the soil organic matter reserve decomposes at an extremely rapid rate. Furthermore, the high rainfall effects strong leaching of the soluble mineral nutrients, so that within a short while successful crop growth becomes well nigh impossible,— unless soil fertility is restored artificially.

The wasteful practice of shifting cultivation carried out on steep lands without due precaution often results in accelerated erosion which further deteriorates productivity. This practice also makes inefficient use of arable lands, since each village-unit requires much greater areas than it can cultivate at any given time. Thus, if it were possible to institute permanent cultivation, vast tracts could become available for expanded agricultural production.

The great and unrealized potentialities of the region lend importance to the study of its soils. Unfortunately, little data is as yet available on either the fundamental aspects of soil genesis and classification, or the more utilitarian aspects of soil properties as they affect crop production.

The present study is an attempt at a basic characterization of a typical upland soil. The soil described was encountered in the course of a field-crops pilot project carried out in 1957-58 by the Israeli Agricultural Mission to Burma.

II. PROFILE MORPHOLOGY

The typical upland soils of the Shan Plateau are residual lateritic red loams. Apparently similar soils were described elsewhere (as in central Africa, by Mohr and van Baren 1954). La Touche (as quoted by Chhibber 1934) compared them with the terra-rossa of Mediterranean countries.

The profile consists of a light reddish-brown surface layer (A–horizon), about 30 cm in thickness, of friable crumb structure and a fair content of organic matter. The subsoil assumes a deep brick-red color and tight columnar structure. No clear differentiation between a B and a C horizon is apparent; the soil extends rather uniformly to considerable depth (often more than 3 metres), and generally rests directly on its calcareous bedrock.

The structure of the surface soil is quite stable and does not slake down easily even under the direct impact of heavy rains. The infiltration rate appears to be high and the runoff rate correspondingly low. Internal drainage is excellent. The soil thus possesses basic properties which are essentially favourable from the standpoint of agricultural use.

III. METHODS OF STUDY

Location and sampling

The profile chosen was of a newly-cleared forest tract lying south of the Kywegon Experimental Farm near the town of Kyaukme, along the Mandalay-Lashio road. The gently sloping land (2–5%) has apparently been under an extensive rotation

of taungya and shrub-forest for many years past. The soil cannot therefore be considered "virgin" in the strictest sense.

Three representative sampling sites were chosen. Pits were dug to a depth of 2 metres, and the exposed profiles examined. Samples were taken from the sides of the pit for each 30 cm interval.

The samples were dried in the air, then passed through a 2 mm standard sieve. Separate undisturbed samples were taken of naturally moist clods and stored in moisture-tight containers for bulk-density determinations.

Numerous additional profiles in different upland tracts were examined by means of auger-borings and were found to correspond in appearance with those of the sampled pits.

Chemical determinations

For the most part, the procedures followed were those recommended by Piper (1950). The following tests were made:
Free iron oxide content by Drosdoff and Truog's method;
Lime content by means of a gasometric calcimeter;
Acidity by means of a Cambridge *p*H-meter on a 1 : 1 soil-water suspension;
Organic matter content by the wet combustion method;
Nitrogen content by the Kjeldahl method;
Potash content by the perchlorate method;
Exchange capacity by the ammonium – acetate method.

Physical determinations

The following tests were made:
Mechanical composition by the pipet method. Dispersion was effected with sodium hydroxide;
Silt and clay in stable aggregates calculated from the difference between the amount of particles smaller than 20 μ obtained with chemical dispersion, and the amount obtained without dispersion. The ratio of this difference to the total amount of silt and clay was expressed as a percentage, and was taken to represent microaggregate stability;
Bulk density by means of the paraffin-coating method;
Saturation percentage by the method of Richards (1954). This is a rather rough measurement of the soil moisture content at saturation;
Field capacity by oven-drying of samples taken from bare plots several days after a rain;
Wilting percentage was evaluated roughly by repeated sampling of the 30 – 60 cm depth under a crop of oats during the dry season;
Hygroscopic coefficient by equilibration with an atmosphere at 50% humidity.

Soil moisture data

Moisture regime governing the growth of a grain crop during the dry season was followed by periodic samplings in a field of closely-growing oats.

IV. RESULTS AND DISCUSSION

Chemical Properties

Sample and Depth (cm)	% Free Fe_2O_3	% $CaCO_3$	Acidity — *p*H March	August	% Organic Matter	% Nitrogen	% K_2O	Exchange Capacity m.e./100g
0 - 30	15.1	0.09	4.8	4.1	2.5	0.16	0.70	11
30 - 60	14.8	0.04	4.8	4.0	1.2	0.10	0.46	8
60 - 90	14.5	0.04	4.9	4.3	0.7	0.08	0.48	6
90 - 120	14.6	0.04	5.2	3.8	0.4	0.05	0.63	5
120 - 150	15.0	0.05	5.0	4.2	0.8	0.06	0.42	5

Free iron oxide content is in the order of 15% and uniform throughout the profile. No distinct zone of iron accumulation was found within the depth sampled. The formation of a lateritic pan may be precluded by the sloping topography, which promotes free drainage and a steady rate of natural erosion.

Lime content of the profile is negligible. Since the soil was formed of a calcareous parent-rock, the absence of lime is indicative of the extreme degree of chemical weathering which occurs under the prevailing warm and humid climate.

Acidity measurements indicate a *p*H value of about 5 for the March samplings, and about 4 for the August samplings. The pronounced acidity is apparently a natural consequence of the removal of calcium and other bases from the soil. The drop in *p*H during the rainy season is apparently related to the strong leaching and decomposition of organic matter which take place during this season. Experiments have shown that crop yields can be increased significantly by additions of lime (Israeli Agricultural Mission 1958).

Organic matter content is highest in the uppermost layers, and drops to very low values below 60 cm. Analyses of samples from nearby cultivated fields within the Kywegon Farm show that the percentage in the uppermost layer drops from 2.5 in the "virgin" soil to 2.16 in a soil that was under cultivation for 2 years, and finally to 1.74 in a soil that was under continuous cultivation for at least 5 years (I. A. M. 1958).

Nitrogen content follows the same general trend as the organic matter content. The correspondence is rough, however, and the C/N ratio is variable. The nitrogen values are low, and field experiments have shown that the addition of appreciable amounts of nitrogen is a prerequisite for successful crop production. No corresponding figures are available for phosphorus content, but the same experiments also indicate

that the soil is deficient in available phosphorus as well (I. A. M. 1958).

Potash content is fair. This explains the rather limited response of experimental crops to potash fertilization (I. A. M. 1958).

Exchange capacity is rather low in relation to the fine texture. The higher value for the uppermost layer is at least partly due to the higher organic matter content. The generally low values, however, indicate the absence of montmorillonitic and illitic clay minerals, and the preponderance of sesquioxides and perhaps kaolinite within the clay fractions.

Physical properties

Sample and Depth (cm)	Mechanical composition % Coarse sand	Fine sand	Silt	Clay	% Silt & Clay in stable aggregates	Bulk density g/cm³ At field capacity	At air dryness	Saturation percentage %	Field capacity %	Wilting point %	Hygroscopic coefficient %
0 – 30	4.3	12.8	57.1	25.8	79.5	1.20	1.31	68	37.5		3.5
30 – 60	4.5	13.4	58.9	23.2		1.12	1.25	68	40.7	22	3.0
60 – 90	4.0	14.8	56.2	25.0		1.17	1.27	69	41.8		3.1
90 – 120	4.6	12.0	48.8	34.6		1.10	1.24	70	43.4		3.7
120 – 150	4.9	11.3	46.8	37.0		1.11	1.27	70	42.2		3.1

Mechanical composition shows that the soil is a rather fine silt loam, becoming a clay loam in the deeper layers.

Silt and clay in stable aggregates amount to nearly 80%. This indicates highly stable aggregation, possibly due to cementation by iron oxide.

Bulk density indicates porosity greater than 50% by volume. Comparision of the values at field capacity and air dryness shows that swelling and shrinking within this range is not very pronounced.

Saturation percentage is in the order of 70%; the soil apparently does not absorb excessive amounts of water at saturation.

Field capacity is close to 40% — a rather high value. The wilting point is estimated at 22%. The "available" range is therefore about 18%, — indicating a good capacity for moisture storage.

Hygroscopic coefficient is about 3% and is fairly constant throughout the profile.

Soil moisture data

Soil moisture in a field of oats during the dry season

Depth (cm)	Moisture content	Date of Sampling: 8.10.57	22.10.57	22.11.57	9.12.57	29.1.58
0 – 30	% of dry weight	37.3	34.2	23.4	19.9	14.9
	equivalent in mm	137	124	86	74	53
30 – 60	% of dry weight	38.1	36.7	28.0	25.6	22.0
	equivalent in mm	140	135	101	94	81
60 – 90	% of dry weight	39.5	39.6	32.1	30.6	27.8
	equivalent in mm	145	145	117	112	101
90 – 120	% of dry weight	41.2	39.3	36.7	33.3	32.3
	equivalent in mm	150	145	135	122	119
120 – 150	% of dry weight	40.9				38.4
	equivalent in mm	150				140

The decline in moisture content of the uppermost layer is due partly to direct atmospheric drying of the surface soil. The decline in moisture content of the second layer, to a steady value of 22%, is probably due almost entirely to extraction by the crop. Since the crop was growing under conditions of moisture stress, this value

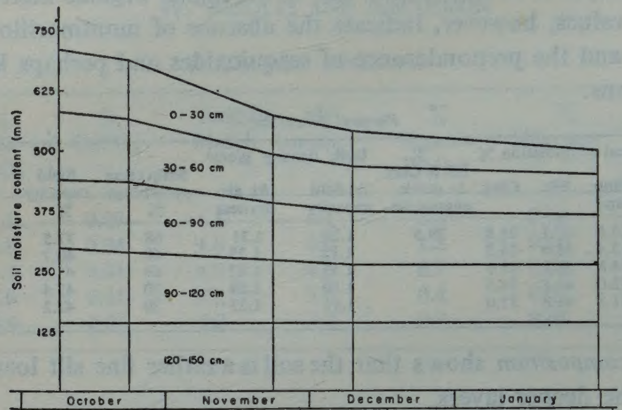

Figure 1
Soil moisture (per 30 cm layers) in a field of growing oats. Dry season 1957–58. (Planting date: Oct. 3; harvesting: Feb. 8)

may be a rough indication of wilting percentage. The deeper layers were utilized only partly by plant roots, while the deepest layer largely retained its original moisture content.

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FOSSIL MAMMALS FROM JISR BANAT YAQUB, SOUTH OF LAKE HULEH, ISRAEL

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ABSTRACT

The fossil mammalian fauna from Jisr Banat Yaqub contains *Elephas trogontherii* Pohlig and other characteristically Middle Pleistocene forms, which indicate that the beds of Jisr Banat Yaqub may be assigned to the Great Interglacial (Mindel-Riss). A most interesting element to the fauna referred to in the Addendum is *Stegodon*, which forms a link between the southeastern Asiatic and the African stegodonts, and which will be fully reported upon later.

The fossil remains of mammals described in the present paper have been collected during the past twenty-five years near the old bridge Jisr Banat Yaqub about 4 km south of Lake Huleh in northern Israel. The site was discovered only in 1933 when, during drainage work , the bed of the Jordan was lowered. From the debris left on the river bank Miss D.A.E. Garrod and Miss E. W. Gardner picked up hand-axes and fossilized bones, and a few trial pits were made. Arrangements for a survey of the bone-bearing and implementiferous beds were made by Dr. M. Stekelis of The Hebrew University of Jerusalem. Under the auspices of the Department of Antiquities excavations started in March 1936, with soundings below the old bridge Jisr Banat Yaqub and in the river-bed itself. Molars and bones of elephants were obtained, which were identified by Miss D. M. A. Bate (Stekelis, Picard and Bate 1937) as *Elephas trogontherii* Pohlig. Remains of Cervidae and Equidae were also discovered. The second season began in March 1937, on the left shore of the Jordan, near the old bridge. The stratification was as follows (Stekelis, Picard and Bate 1938):

Layer A (0 – 0.42 m): Upper gravel of the old Jordan bed with few flint implements of Levallois technique.

Layer B (0.42 – 0.60 m): Yellowish clay of the transition zone with basalt pebbles; molars and a few broken bones of elephants; flint implements of Acheulean technique.

Layer C (0.60 – 0.92 m): Green clay with few basalt pebbles; molars and bones of elephants and other animals; flint implements of the same type as in B.

Layer D (0.92 – 1.10 m): Lower black soil with basalt, flint, and limestone boulders, containing abundant fauna of molluscs (*Melanopsis*, *Vivipara*), elephant tusks, molars, and parts of skeletons; flint and basalt implements of lower Acheulean technique.

The fossil mammalian specimens collected in 1935 (without a record for the level

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from which they came) and in 1937 (derived from layers D, C, and B) were sent to the British Museum (Natural History) for study and description by Miss Bate. Some of the material of the 1936 season was retained by the Hebrew University. After the war, Dr. Stekelis resumed work at the Jisr Banat Yaqub site, and was able not only to collect more specimens from the layers already excavated in 1937 but also to dig deeper into Layer D, discovering two more bone-bearing and implementiferous layers, as follows (Stekelis 1956):

Bed IV (in part Layer D of 1937) (0.90 – 2.50 m): Black soil with limestone and basalt boulders; abundant fauna of molluscs; complete tusk of a young *Elephas trogontherii* 1.75 m in length; basalt hand-axes heavily rolled and abraded; Acheulean flint hand-axes.

Bed V (2.50 – 3.40 m): Black hardened soil with abundant fauna of molluscs; very rich basalt industry (hand-axes and cleavers) in fresh condition as well as abundant fossilized bones; *Elephas meridionalis*, *Rhinoceros* sp., *Hippopotamus* sp. Old Acheulean.

Bed VI (3.40–5.50 m): Gravels of basalt with remains of fractured and rolled basalt artifacts.

Miss Bate unfortunately never completed the description of the fossil mammalian fauna from Jisr Banat Yaqub; at the time of her death in 1951 there were only a few notes on the possible identity of the elephant (which she had already correctly identified as *Elephas trogontherii* in 1936), and the material was still in the British Museum (Natural History). Learning that the fauna obtained by Dr. Stekelis since the war, and preserved in the Department of Prehistoric Archaeology of the Hebrew University, also awaited description, and following a suggestion of Professor L. Picard, I decided to study the Jisr Banat Yaqub fauna as a whole. In the summer of 1959 I received in Leiden the collections kept until then in London and in Jerusalem; the latter included an elephant vertebra collected in 1936, various bones and teeth of swine, deer, and bovids from an unstratified deposit at Jisr Banat Yaqub found in 1950, as well as good material of elephants, rhinoceros, hippopotamus, and bison (?) collected in 1951 and 1952. The level at which these specimens were found is not recorded on the labels, but Dr. Stekelis (in letter, October 5, 1959) informs me that all the fossils labelled 1951 are from the base of Bed V, which would contain "*Elephas meridionalis*" as well as *Rhinoceros* and *Hippopotamus* (Stekelis 1956), and which would yield an Old Acheulean industry. However, the elephant remains collected in 1951 and 1952 are as characteristically *Elephas trogontherii* as are those from the layers B–D of the 1937 season. I have not seen the complete tusk from Bed IV recorded by Dr. Stekelis; in the 1935 collection there are a few fragments of tusks, which are of no value for identification purposes, however.

The fossil mammalian fauna of Jisr Banat Yaqub comprises eight species as far as known at present, and will be described in the following pages. I wish to acknowledge my indebtedness to Professor L. Picard and Dr. M. Stekelis of the Hebrew University, Jerusalem, for having entrusted this interesting fauna to me for description.

Order Proboscidea — Family Elephantidae

Elephas trogontherii Pohlig

The molars of this species are rather variable, but are intermediate between those of *Archidiskodon meridionalis* (Nesti) of the Early Pleistocene and those of *Elephas primigenius* Blumenbach of the Late Pleistocene, morphologically as well as stratigraphically. In plate formula they resemble *Elephas antiquus* Falconer, but the enamel figures of the plates, forming broad bands with irregular, mostly median, expansions, do not resemble the loxodont sinuses characteristic of *E. antiquus* except in advanced stages of wear. The enamel is relatively thick (2–3 mm in M2–3), crimped and often festooned; slightly worn plates show a division into a broad lamellar median portion and two narrower lateral portions. The lateral portions, although often termed "annular" in descriptions, nevertheless remain transverse ovals; in *E. antiquus* they are still narrower transversely and may properly be called annular. The most representative series of molars of *E. trogontherii* are from the Early post-Villafranchian site of Süssenborn, Germany (Pohlig 1888-1891, Wüst 1901, Soergel 1912). As will appear from what follows, the Jisr Banat Yaqub elephant molars collected in 1935 and 1951–1952 as well as those from levels B–D of the 1937 season are within the variation limits of their homologues in *Elephas trogontherii*, and thus should be referred to that species, as already believed by Miss Bate (Stekelis, Picard and Bate 1937).

UPPER MOLARS

An upper right first molar from layer B (JBY B 1) carries eleven plates, nine of which are worn (pl. III fig. 2). Of the anterior four plates only the lingual halves are preserved. Plates 5 and 6 are slightly damaged apically on the lingual side, but they clearly show the subdivision of the enamel figure into a broad central part, one-half as wide as the total figure, and two smaller lateral portions, which are less expanded anteroposteriorly than the central portion. In plate 5 these lateral portions have just united with the central figure; in plate 6 they are separate. The width of the enamel figure of plate 5 is 51 mm, that of plate 6, 45 mm; the width at the base is 57 mm in both plates. The height of plate 5 is 115 mm, that of plate 6, 125 mm, in their slightly worn state. Plate 7 is almost entirely gone. Plate 8 carries 6–7 conelets, worn to enamel rings only partially coalesced. Of plate 9 six conelets, just touched by wear, protrude from the cement that covers the apical portions of plates 10–11 and of the posterior talon. Unfortunately the base of the crown behind plate 7 is not preserved, and the full height of the unworn plates, therefore, cannot be given. The posterior four plates increase slightly in transverse diameters from the top of the crown toward the base; plates 8, 9, and 10, 135 mm high as far as preserved, are at most 45–50 mm wide in their apical third, while their greatest width near the base is over 60 mm. Plate 11 is only slightly produced buccally and measures about 50 mm transversely near the base; the talon width is 36 mm. The enamel thickness is 1–1½ mm.

The greatest length of the crown of the Jisr Banat Yaqub M^1, in the median

line at right angles to the plates and including the posterior bulge, is 164 mm. The length/plate ratio of this eleven-plated molar, counting the thick posterior talon as one additional plate, is $164:12 = 13.7$. This ratio ("Längen-Lamellen-Quotient": Soergel 1912) varies from 11.4 to 13.5 in four specimens of M^1 of *trogontherii* from Süssenborn (Soergel *loc. cit.*, Table IV). The plate formulas of two entire Süssenborn specimens are $x10x$, and $x12x$, respectively; their lengths are 141 mm and 169 mm. The widest enamel figures of these Süssenborn molars, which have 8–9 worn plates, occur in plate 3 and are 59–69 mm transversely, but in a Mosbach specimen incomplete anteriorly and with nine plates worn, just as our specimen, the widest enamel figure is that of plate 5, and it is 54 mm wide (Soergel *loc. cit.*). Height measurements of unworn plates are not available; those of apparently slightly worn plates amount to 123 mm (Wüst 1901, Table III). The thickness of the enamel in the German specimens of M^1 of *trogontherii* varies from 1 to 2mm, and the plates, divided apically into a wide median and two narrower (annular) lateral portions, do increase in width down to the base.

In all its characters the present Jisr Banat Yaqub M^1 is a typical *trogontherii*.

In the 1935 collection there is the anterior portion of a left M^1 (JBY 1935 4) comprising four plates. The anterior plate is damaged in front; all the plates are worn to a slight extent. The fourth plate still shows the characteristic tripartite enamel figure, and is 115 mm high by a uniform width of 52 mm. In its thinnish enamel (1mm) and in the length/plate ratio, which is $42: 3 = 14$, this fragment resembles the foregoing specimen closely.

The best specimen of M^2 in the collection is a molar in situ in a portion of the left maxillary, originating from layer D (JBY D 1). The crown is entire, and eleven of the twelve plates are worn, presenting an anteroposteriorly convex, oval-shaped grinding surface (pl. II figure 1), that falls off slightly toward the buccal side. The roots are exposed buccally; there is a distinct anterior root supporting the first two plates, while the remaining roots, diminishing in size from front to back, are fused to a variable extent at their bases, most markedly so those of plates 4–5 and 7–8. The free root tips are recurved backward. There is a coat of cement all around the crown; it is partially lost along the buccal margin (pl. I figure 2).

The enamel figures of the first two plates have coalesced; those of plates 3 to and including 8 are single, forming broad bands, indistinctly expanded in the middle, with crimped enamel 2 mm thick, and slightly curved backward at either end, especially buccally. Plates 9 and 10 present tripartite enamel figures, the central part being the widest. In plate 9 it occupies one-half the total width of the enamel figure (52 mm); in plate 10 the central figure is likewise 26 mm wide but the lateral portions measure only 8–9 mm transversely. Of the eleventh plate only the central portion appears above the cement; it consists of four conelets that have a total width of 20 mm. The twelfth plate and the talon are concealed by cement.

The greatest length of the crown is 213 mm. The greatest width of the cr own

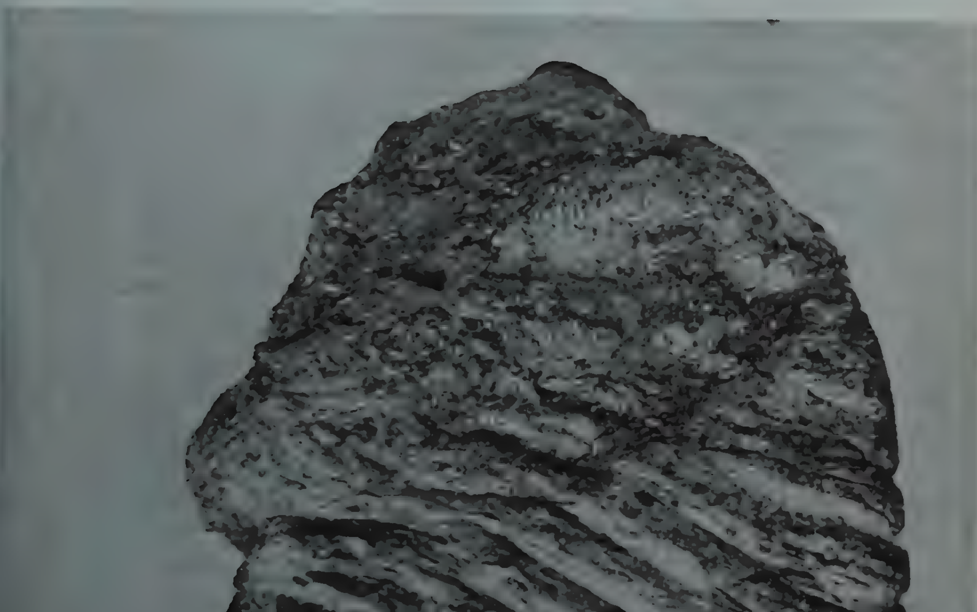

PLATE 1 — Figure 1

Elephas trogontherii Pohlig, Middle Pleistocene, Jisr Banat Yaqub, Israel; M^3 dext. (JBY 1951 1), outer view. Figure ½ natural size.

Plate I — Figure 2

Elephas trogontherii Pohlig, Middle Pleistocene, Jisr Banat Yaqub, Israel; M^2 sin. (JBY D 1), outer view. Figure ½ natural size

PLATE II

Elephas trogontherii Pohlig, Middle Pleistocene, Jisr Banat Yaqub, Israel; fig. 1, M^2 sin. (JBY D 1), crown view; fig. 2, M^2 sin. (JBY 1951 2), crown view; fig. 3, M^2 dext. (JBY 1952 1), crown view. All figures ½ natural size.

PLATE III

Elephas trogontherii Pohlig, Middle Pleistocene, Jisr Banat Yaqub, Israel; figs. 1 and 3, M_2 sin. (JBY C 2); fig. 1, crown view; fig. 3, outer view; fig. 2, M^1 dext. (JBY B 1), inner view. All figures ½ natural size.

PLATE IV

Figs. 1, 4, and 5, *Equus cf. caballus* L., Middle Pleistocene, Jisr Banat Yaqub, Israel; fig. 1, M_1 dext., crown view; fig. 4, M^1 sin., crown view; fig. 5, P^3 dext., crown view. — Fig. 2, *Dicerorhinus merckii* (Jäger), Middle Pleistocene, Jisr Banat Yaqub, Israel, P^4 sin., crown view. — Fig. 3, cf. *Bison priscus* (Bojanus), Middle Pleistocene, Jisr Banat Yaqub, Israel, portion of horn core. — Figs. 1, 2, 4, and 5, 4/3 natural size; fig. 3, ½ natural size.

including the cement investment, is at the level of plate 6 and amounts to 86 mm. The widest enamel figure shown on the occlusal surface is that of plate 5, and is 73 mm wide. The height of the slightly worn tenth plate is 140 mm.

The laminar frequency (the number of plates per 10 cm of anteroposterior length, that is) is $5\frac{1}{2}$ on the grinding surface, but is 6 when taken at right angles to the plates; the grinding surface forms an angle of about 65° with the plates. The length/plate ratio of the present Jisr Banat Yaqub M^2 is 213:13 = 16.4.

There is very much variation in the series of M^2 of *trogontherii* from Süssenborn and Mosbach recorded by Wüst (1901, Table II) and by Soergel (1912, Table VI). The number of plates varies from 11 to 17; in our specimen it is 12. The length of our specimen (213 mm) is intermediate, for the German specimens vary in length from 168 mm in an eleven-plated M^2 to 240 mm in a fourteen-plated specimen. Consequently, the length/plate ratio is rather high: 16.4 in our specimen as compared with 12.8 to 17.9 in the German series. The greatest width of the widest plates of four Süssenborn M^2 given by Wüst (1901, Table II) is 84–90 mm; in our specimen it is 86 mm. The width measurements given by Soergel (1912, p. 18), in contradistinction to those presented by Wüst (*loc. cit.*, p. 265), are only those of the widest enamel figures shown on the occlusal surface, exclusive of cement. In four German specimens in approximately the same stage of wear as our specimen (10–11 worn plates) the widest enamel figures (plates 3–5) measure from 68 to 95 mm transversely, a range that includes the observation of our specimen (73 mm). Heights of the least worn plates in three molars in the same stage of wear (10–11 plates worn) vary from 138 to 156 mm (140 mm in our specimen). The enamel thickness may vary from 1 to 3 mm but averages 2 mm. Most of the German specimens display the typical "lat. ann. med. lam." division of the figures of slightly worn plates. Thus, there appears to be no character in which the Jisr Banat Yaqub M^2 differs from *E. trogontherii*.

Similar, but less well preserved, is an M^2 dext. likewise from layer D (JBY D 3). Incomplete anteriorly as well as basally, it carries eleven plates, all but the last of which worn to single enamel figures. The widest enamel figure (plate 4 from the front) is 70 mm transversely. The laminar frequency is 6, and the length/plate ratio is 145: 9 = 16.1, both taken in the median line of the occlusal surface.

Another M^2, from the right side, broken off behind the ninth plate and originating from layer B (JBY B 2), lacks the roots and is slightly less worn than the preceding specimens. It has a height of about 165 mm at the slightly worn ninth plate by a greatest width of 81 mm. Six enamel figures are entire, the three others are subdivided in the "lat. ann. med. lam." fashion. Nine plates occupy 135 mm anteroposteriorly, giving a length/plate ratio of 15.0, lower and thereby more progressive than that of the foregoing M^2. The widest enamel figure (plate 5) measures, again, 73 mm transversely. The enamel appears to be thinner than that of the M^2 sin. from layer D, $1\frac{1}{2}$–2 mm, another progressive feature.

In the collection from Jisr Banat Yaqub sent to me from Jerusalem there are two specimens of M^2, almost entire, originating from the base of Bed V (Dr. Stekelis,

in letter, October 5, 1959). The first of these (pl.II figure 2) is from the 1951 excavations and is from the left side (JBY 1951 2). It is broken off in front of the eleventh plate from behind. All the plates are worn; the penultimate plate has a tripartite figure (lat. ann. med. lam.), and the last plate shows four conelets. Height measurements cannot be given; the greatest width of the crown (cement included) is 82 mm, while the widest enamel figure measures 75 mm, both at plate 7 from behind. The laminar frequency is $6\frac{1}{2}$, and the length/plate ratio is 152:10 = 15.2. The other M^2, from the right side, likewise incomplete in front (pl. II figure 3) is from the 1952 excavations (JBY 1952 1). Nine plates are present (there is an abraded area of dentine to the front comprising at least two more plates); plates 1–4 from behind present tripartite figures. The greatest width (plate 6 from behind) is 80 mm, cement included; the enamel figure of the seventh plate from behind is the widest (75 mm). The laminar frequency on the grinding surface is 5, whereas that taken at right angles to the plates is 6. The length/plate ratio is 156: 9 = 17.3, rather higher than that in the preceding specimen but still within the limits of the German series of M^2 of *E. trogontherii* given above.

This completes the descriptions of the second upper molar in the Jisr Banat Yaqub collection, a series of five specimens each with all the characteristic features of *Elephas trogontherii*. Before passing on to the last upper molar I shall enumerate a number of fragmentary specimens.

A large portion of an upper molar, either M^2 or M^3, found in 1935 and hence without a record for the layer from which it came, is incomplete at both ends (JBY 1935 2). There are seven plates, six of which worn, in 95 mm of anteroposterior length (length/plate ratio 13.6), which shows the present specimen to be even more progressive than that of layer B mentioned above. The height of the unworn hindmost preserved plate is 175 mm; the greatest width of the same plate is only 67 mm. The greatest width of the crown (cement included) is at the foremost preserved plate, and is 86 mm; the widest enamel figure (same plate) is 77 mm wide. The plates are slightly convex to the front, and the enamel figures are irregularly expanded, with several large festoons; the last two plates show the apices of six conelets. The enamel is $1\frac{1}{2}$ to 2 mm in thickness.

The present specimen appears to be outside the range of variation of M^2 of *trogontherii* in its greatest height (175 mm as opposed to 162 mm at most: Soergel, 1912, table VI), and, therefore, it may represent an M^3. However, the maximum width of the present specimen is less than that in M^3 of *trogontherii* (see below), and agrees better with that of M^2 (84–90 mm: Wüst 1901, Table II).

An unworn plate with part of an adjacent plate (JBY 1935 3) belongs to an upper molar very similar to the last; it is only very slightly higher relative to its width than the hindmost plate of that specimen. The full height (measured at the highest, internal in upper molars, side) is 192 mm, the greatest width (at one-third of the height from the base) is 73 mm. It presumably represents one of the posterior full plates of a high-crowned M^2 or of a narrow-crowned M^3.

A much abraded anterior portion of an upper penultimate or last molar from layer C (JBY C 1) comprises four plates with sub-loxodont enamel figures reminding one of those of *Elephas antiquus*. Such figures do develop in much worn *trogontherii* molar plates (Soergel 1912, pl. III figure 6). The greatest observed width (plate 4) is 77 mm, the enamel thickness, 2 mm. Three plates measure 42 mm anteroposteriorly, and the length/plate ratio, therefore, is 14.

A fragment of an upper molar holding three plates, originating from layer B (JBY B 3), is slightly worn but incomplete basally. The greatest width is 80 mm, the anteroposterior length of three plates is 51mm, giving a length/plate ratio of 17.

A specimen of the 1935 season comprises a large fragment of a plate, the greatest width of which is 85 mm (JBY 1935 5). Parts of two more plates are attached to it, proving it to belong to an upper molar the length/plate ratio of which is 17. Neither the top nor the base of the largest plate are preserved; this specimen, like the preceding, shows quite well the characteristic subdivision into a broad central part flanked by much smaller but still transversely oval portions. The enamel thickness amounts to 2–2½ mm.

There can be no doubt about the serial position of a fragment of an upper molar of the 1935 season comprising one entire and parts of three more plates (JBY 1935 1). The entire plate has a height of 215 mm by a width of 96 mm. This specimen is very near the maximum height recorded for a *trogontherii* M^3 (from Mosbach), *viz*., 218 mm (Soergel 1912, Table VIII). The maximum width of M^3 of *trogontherii* is 90–110 mm (Wüst 1901, Table I). Three plates and three cement intervals measure 54 mm anteroposteriorly, giving a laminar frequency of 5.6, and a length/plate ratio of 18. This ratio varies widely in M^3 of *trogontherii*, from 12.2 to 21.0 (Soergel, *loc. cit.*). The thickness of the enamel is not less than 3 mm, exceeding that in the molars already described above.

A right M^3 from the 1951 excavations, with part of the maxillary still attached to it (JBY 1951 1) holds 19 plates, 12 of which worn. A few plates are missing in front. The crown, with its cement investment, is widest at plate 9 from the front (93 mm); the height of the foremost unworn plate is ca. 170 mm. The total length of the molar, from front to back, at right angles to the (19) plates, is 276 mm, which gives a length/plate ratio of 14.5. The enamel is not very thick: ca. 2 mm. In all these figures the present specimen closely resembles a 22-plated M^3 from Süssenborn recorded by Wüst (1901, pl. II, no. 11, Table I). The Jisr Banat Yaqub M^3 is figured on pl. I figure 1. From the same season is the hinder portion of an M^3 dext. (JBY 1951 4) comprising 8 plates increasing gradually in width from 29 to 83 mm, and in height from ca. 90 to ca. 165 mm, when passing forward along the plates. The length/plate ratio is $125:8 = 15.6$. The level from which the 1951 specimens came is the base of Bed V, at a depth of 3.40 m; in their characters the 1951 molars that I have seen are as characteristically *trogontherii* as are those from levels B–D obtained before the last war.

LOWER MOLARS

A left lower second molar from layer C, broken off behind the eleventh plate (JBY C 2) has all the preserved plates worn (pl. III figures 1 and 3). The height of the last plate is 125 mm; in the unworn state it would have been at most 130 mm high. The greatest width (at plate 8) is 80 mm; the widest enamel figure (plate 6) is 66 mm wide. The laminar frequency is 6 on the concave buccal side against 5 on the convex lingual surface. The enamel figures of the heavily worn anterior plates are lozenge-shaped, *antiquus*-like, but the moderately worn plates 6 and 7 present enamel figures that are not expanded in the centre. Plates 8 and 9 exhibit a median cleft, dividing the enamel figure into two subequal portions (pl. III figure 1). Such median clefts are occasionally found between the normal tripartite plate figures in *E. trogontherii* as well as in other elephant species (Soergel, 1912). Plates 10 and 11, although they do show a slight posterior dislocation of the buccal part, present the normal elephantine division into a wide central and two narrow lateral pillars. The enamel thickness is 2 mm. Eleven plates occupy 174 mm of anteroposterior length, and the length/plate ratio hence is 15.8.

Lower second molars of *Elephas trogontherii* from Süssenborn (Soergel, 1912, Table V) vary in length/plate ratio from 15.5 to 16.9; the width of the widest enamel figure in these molars (with 10–12 plates worn) varies from 61 to 91 mm; the height of slightly worn plates from 69 to 129 mm. The Jisr Banat Yaqub M_2 is well within these limits.

The greater part of a much worn right lower last molar from layer D (JBY D 2) comprises thirteen plates; the front, showing the coalesced dentine surfaces of at least two plates, is incomplete, while behind a few plates appear to be missing as well. The hindmost preserved plates are only slightly worn, but their height cannot be determined because of the poor state of preservation of the specimen. The anterior enamel figures are slightly expanded in the middle; the enamel is 2–3 mm thick and moderately crimped. The widest enamel figure shown (plate 7 from the front) measures only 68 mm transversely; the greatest observed width of the molar is about 75 mm, but would have been greater if the enamel coat lingually had been present. The enamel figures of plates 11, 12, and probably 13 as well, show a median cleft, as is likewise the case in some of the plates of the M_2 recorded above. The laminar frequency is $4\frac{1}{2}$ lingually and slightly over 5 buccally due to the curvature of the specimen. Eleven plates occupy 200 mm of anteroposterior length; the length/plate ratio is 18.2.

In the last lower molars of *trogontherii* from Süssenborn the length/plate ratio ranges from 14.0 to 19.5 (Soergel, 1912, table VII), and the width of the widest enamel figures runs from 62 to 100 mm, which makes the present Jisr Banat Yaqub M_3 appear to be rather narrow-crowned. The greatest width in the Süssenborn specimens of M_3 recorded by Wüst (1901, Table I) varies from 90 to 105 mm, but Pohlig (1888–1891, figure 82) mentions a "sehr typisch" M_3 82 mm wide, and even records one that is only 67 mm wide (*loc. cit.*, figure 89). Thus, in width as well as in the other characters the Jisr Banat Yaqub M_3 is within the limits of *Elephas trogontherii.*

THE VALUE OF *Elephas trogontherii* AS AN INDEX OF THE AGE OF THE JISR BANAT YAQUB DEPOSITS

The only elephant molars of Jisr Banat Yaqub with a record for the layer from which they came are from layers B–D (0.42–1.10 m) (1937 season), and from the base of Bed V (3.40 m) (1951 season).

The material of upper penultimate and last molars of *Elephas trogontherii* from Jisr Banat Yaqub does not give evidence for a progressive change as we pass upward along the series of layers in which this species occurs. From the base of Bed V (3.40 m) there are two M^2 with length/plate ratios of 15.2–17.3. In layer D (1.10–0.92 m) two M^2 have length/plate ratios of 16.1–16.4; in layer C (0.92–0.60 m) there is an M^2 or M^3 in which this ratio is 14, whereas two specimens from layer B (0.60–0.42 m) have length/plate ratios of 15.0–17. The penultimate and last upper molars obtained in 1935 vary between even wider limits in the length/plate ratio, viz., from 13.6 to 18. This variability in length/plate ratio is likewise characteristic of the *trogontherii* molars from Süssenborn and Mosbach, as we have seen above.

In England *Elephas trogontherii* ranges from the Cromer Forest Bed (in part Günz-Mindel Interglacial: Azzaroli 1952) up to and including the Clacton-on-Sea stage (Mindel-Riss Interglacial) (Hopwood, 1937). In Germany *Elephas trogontherii* appears last in the Saale river terraces (Riss Glacial II) in which elephants of the *primigenius*-type begin to replace it (Zeuner 1945).

The Jisr Banat Yaqub *E. trogontherii* represents the stage of development in the *Archidiskodon meridionalis* — *Elephas trogontherii* — *Elephas primigenius* lineage that prevailed in Europe during the Mindel-Riss Interglacial (Süssenborn, Mosbach, etc.). It is more progressive than the Villafranchian *Archidiskodon meridionalis*, in which the height of M^3 does not exceed 140 mm (Weithofer, 1890); the Jisr Banat Yaqub M^3 has a height of 170–215 mm. On the other hand, it is less advanced than *Elephas primigenius*: the length/plate ratios in the Jisr Banat Yaqub M^3 and M_3 are 14.5–18, and 18.2, as opposed to at most 12.5 in M^3, and 13.5 in M_3 in *Elephas primigenius* (Soergel 1912, Tables VII–VIII; Guenther 1956).

Osborn (1942, chapter XVII) is at variance with the opinion of the German authors (Pohlig, Soergel, and most recently Adam 1952) that *Elephas trogontherii* is a connecting link between *Archidiskodon meridionalis* and *Elephas primigenius*; he believes that *E. trogontherii* belongs to an entirely distinct "generic phylum" (*Parelephas* Osborn) that appears first in the Villafranchian of Italy, and reappears in the more temperate Interglacials of southern and eastern Europe up to the 3rd Interglacial. It did not give rise to the mammoth *Elephas primigenius* but migrated in an Interglacial (the 3rd: Osborn *loc. cit.*, pp. 1049, 1067; or the 2nd and even possibly the 1st: *loc. cit.*, pp. 1071, 1587) through Asia Minor and Asia to the United States, Mexico, and French Guiana. The occurrence in Asia Minor of the *Elephas trogontherii* "phylum" is *Elephas armeniacus* Falconer, based on an M^3 of uncertain stratigraphic position found near Khanoos, Province of Erzerum, Armenia, which is in about the same stage

of evolution as that of *Elephas trogontherii* of Germany (*loc. cit.*, pp. 1060–1062). Indeed, had this molar been found at Süssenborn it would doubtless have been identified as *Elephas trogontherii* .The Armenian record is the most easterly of the species, and the occurrence at Jisr Banat Yaqub extends the area from which *Elephas trogontherii* is known southward into the eastern Mediterranean region.

From the close resemblance between the Jisr Banat Yaqub elephant molars and those of *Elephas trogontherii* from Germany we may conclude that the time of deposition of Bed V to layer B at Jisr Banat Yaqub corresponds approximately with the 2nd or Great Interglacial (Mindel-Riss) of Europe.

In the Jisr Banat Yaqub collection sent to me from Jerusalem there is an atlas excavated in 1936. It lacks only the left transverse process, and is very close in dimensions to the atlas from the Early Pleistocene of Bethlehem provisionally referred to *Archidiskodon* cf. *planifrons* (Hooijer 1958), as shown in Table I. It is

TABLE I
Measurements of atlas of two fossil Israel elephants (in cm)

	Archidiskodon cf. *planifrons* Bethlehem	*Elephas* cf. *trogontherii* Jisr Banat Yaqub
Total height	26	ca. 26
Facies articularis cranialis, vertical	15	13
transverse	ca. 9	8.5
Anteroposterior diam. of corpus	9.5	9
Height of foramen vertebrale	13.5	13
Least width of idem	ca. 6	5.5
Foramen transversarium, diameter	3	4.5
Foramen for first cranial nerve, diameter	1.5	2

extremely probable that the Jisr Banat Yaqub atlas represents *Elephas trogontherii* as do the molars from the same site; there is no evidence of the presence of more than one species of elephant at Jisr Banat Yaqub. The extreme width of the articulating surfaces for the occipital condyles of the skull is 25 cm in the Jisr Banat Yaqub atlas; Soergel (1914) gives the same figure (24.8 cm) for the atlas of *Elephas trogontherii* from Süssenborn. *Elephas antiquus is* larger than the Jisr Banat Yaqub elephant: the extreme width of the cranial articulating surfaces of the atlas in the Upnor elephant is 29.5 cm (Andrews and Cooper 1928), and even 31cm in a skeleton of *Elephas antiquus* from Italy (Trevisan 1948).

ORDER PERISSODACTYLA — FAMILY EQUIDAE

Equus cf. caballus L.

A few teeth, all isolated, indicate the presence of a horse at Jisr Banat Yaqub. There are two upper and three lower cheek teeth, without a record for the level at which they occurred but for one M_1 dext. that is from layer B and that was found during the 1937 season. Another M_1 dext. (pl. IV figure 1) is caballine in having a U-shaped

valley between metaconid and metastylid; the external groove is only one mm distant from this valley, and there is an accessory fold in the anterior surface of the hypoconid. The length of the crown surface is 29 mm, the width is 17 mm. The labelled M_1 is slightly smaller (27 by 16.5 mm); the metastylid is damaged so that the shape of the valley in front of it cannot be determined; the external fold nearly joins the internal. While the fold in the anterior surface of the hypoconid is less marked, there is a small fold in the anterior horn of the fold that enters the crown between metastylid and entoconid, hardly indicated in the first tooth. The third specimen, incomplete behind but most probably M_3 dext., is narrower (width of crown 13 mm), and has a V-shaped valley between metaconid and metastylid. The two uppers, a P^3 dext. and an M^1 sin. (pl. IV figures 4–5), both possess a narrow but distinct caballine fold. The posterior lobe of the protocone is twice as long as the anterior lobe, and the lingual surface of the protocone is concave. The foldings of the pre- and of the postfossettes are very much alike in the two specimens, the pli protoconule is the largest of these folds and extends almost entirely across the prefossette. Whereas in M^1 the anterior horn of the postfossette extends further outward than the posterior horn of the prefossette, in P^3 there is no difference in length between the two horns. The crown of P^3 is nearly square, 25 by 25.5 mm; that of M^1 is 28 mm long by a width of 26 mm.

The characters of the fossil equid teeth can all be matched in *Equus caballus* L. The M_3 has a V-shaped metaconid-metastylid valley, but this zebrine condition usually obtains in M_3 of the caballines as well (McGrew 1944). *Equus hemionus* Pallas, a congener of *Equus caballus* from the Upper Acheulean up into the Natufian of Mount Carmel, as well as *Equus hydruntinus* Regalia from the Levalloiso-Mousterian of Mount Carmel (Bate 1937), can be excluded because they lack the caballine fold, and the metaconid-metastylid valley is not quite U-shaped, although some individual teeth may approach the condition seen in *Equus caballus* (Stehlin and Graziosi 1935, pls. 4–5).

The true caballine horses from the Middle Pleistocene of Europe are in part considerably larger than the horse of Jisr Banat Yaqub (see, *e.g.*, *Equus süssenbornensis* Wüst 1901, pl. VI). There is a host of specific names bestowed on these forms (Dubois and Stehlin 1932–1933). A few isolated teeth, without any accompanying limb bones, would seem to form insufficient material on which to base a specific determination. Since the upper and lower teeth now available uniformly display the caballine features they may be provisionally recorded as *Equus* cf. *caballus* L.

ORDER PERISSODACTYLA — FAMILY RHINOCEROTIDAE

Dicerorhinus merckii (Jäger)

The rhinoceros is poorly represented in the Jisr Banat Yaqub collection: two upper premolars, neither of them entire. The P^3 dext. originates from layer C, and was found in 1937; the P^4 sin. (pl. IV figure 2) was excavated in 1951, and originates from the base of Bed V. The P^3 lacks the external part of the protoloph, the whole of the ectoloph, and the posterior surface as well. The P^4 lacks the ectoloph and the posterior

surface. The entrance to the medisinus forms a high and narrow pass, 22 mm above the enamel base in P^3, and 28 mm above the base in P^4; the anterior cingulum runs steeply upward from the antero-internal angle of the crown; there is no cingulum along the internal surface of the protoloph, but it begins at the inner boundary between proto- and metaloph and forms a strong ridge ascending steeply along the inner surface of the metaloph. The crochet is duplicated in P^3, and bifid in P^4; in the latter tooth it is flanked by two lesser projections. There is a slender crista in both of the fossil premolars, which, however, does not join the crochet. Although measurements cannot be given there cannot be any doubt as to the identification of the Jisr Banat Yaqub premolars: in all observable characters, notably in the steepness of the cingulum at the anterior surface, the high, V-shaped entrance to the medisinus, the absence of a cingulum along the inner surface of the protoloph, and the steep ridge formed by the cingulum at the inner surface of the metaloph the two fossil premolars agree perfectly with those of their homologues in *Dicerorhinus merckii* (Jäger), a species that ranges in Europe from the Villafranchian upward into the Riss-Würm Interglacial, to which most of the well-identifiable remains belong (Dubois and Stehlin, 1932–1933). *D. merckii* occurs in the Upper Acheulean and Lower Levalloiso-Mousterian of Mount Carmel (Bate 1937, as *Rhinoceros* cf. *hemitoechus*; Vaufrey 1951). It differs from the Villafranchian *D. etruscus* present at Bethlehem (Hooijer 1958) in all the points mentioned: in *D. etruscus* upper premolars the anterior cingulum is only slightly inclined upward, the entrance to the medisinus is wide, U-shaped, and there is a horizontal cingulum lingually at the protoloph. Thus, these differential characters, well stated e.g., by Bernsen (1927) who studied European remains of *D. etruscus* and *D. merckii*, appear to hold equally well for the two dicerorhine species in Israel. The development of a crista in the Jisr Banat Yaqub premolars (P^4 represented on pl. IV figure 2) is an individual aberration occasionally shown in the European *merckii* as well.

Order Artiodactyla — Family Suidae

Sus cf. scrofa L.

The only remains of a pig found at Jisr Banat Yaqub consist of a fragment of the right mandibular ramus with M_2 (incomplete) and M_3, collected in 1950 from an unstratified deposit. The last molar is as elongated as that in *Sus scrofa*, having a talonid (with four cusps) as long as the first or the second lobe; the length of M_3 is 36 mm, and the anterior width 18 mm. There would be nothing for it but to identify this fossil specimen with *Sus scrofa*, the European wild boar still found in Israel, and known from Pleistocene deposits in Europe since the Great Interglacial (Mindel-Riss), were it not that Miss Bate has described from the Upper Acheulean and Lower Levalloiso-Mousterian of Mount Carmel an extinct species, *Sus gadarensis* Bate (1937) that differs from *Sus scrofa* mainly in the structure of the premolars. The M_3 of *Sus gadarensis* figured (Bate *loc. cit.*, figure 5d) measures 41 by 20 mm, and does not differ significantly from that of *Sus scrofa*. As long as more diagnostic

specimens of the fossil Jisr Banat Yaqub suid are not available for study it would seem best to place it on record as *Sus* cf. *scrofa L.*

Order Artiodactyla — Family Hippopotamidae
Hippopotamus amphibius L.

The hippopotamus is represented at Jisr Banat Yaqub by three specimens, the tip of a lower left canine, a portion of a right lower canine, and an upper incisor, probably I^2 sin. These teeth, excavated in 1951, and found at the base of Bed V, resemble their homologues in the recent hippopotamus so very closely as to leave no doubt as to their conspecificity. The left lower C, an apical fragment 16 cm long with an abrasion surface extending along the concave inner surface for a length of 8 cm, belonged to an adult individual because it is of an even thickness in its proximal half. It is decidedly smaller in diameters than the portion of the right lower C, but this is evidently only a matter of the difference in sex of the former owners of the two fossil canines. There is a marked secondary sexual difference in the size of the lower canines in *Hippopotamus amphibius* L., the male C being decidedly the larger, and the variation ranges do not even overlap (Hooijer 1950, Table I A). As shown in Table II the smaller of the two fossil lower canines is within the variation range of the recent female, and the larger within the limits of the recent male canines.

TABLE II
Measurements of lower canine of recent and fossil Hippopotamus amphibius L. (*in mm*)

	Recent females (Hooijer 1950)	Jisr Banat Yaqub (sin.)	Recent males (Hooijer 1950)	Jisr Banat Yaqub (dext.)
Circumference	100–132	132	160–195	175
Greater diameter	38–49	50	62–73	66
Smaller diameter	25–34	30	38–51	43

The hippopotamus is known from Europe and Asia since the Early Pleistocene; in Israel it is known from the Upper Acheulean and the Lower Levalloiso-Mousterian of Mount Carmel (Bate 1937) and then again from the Iron Age of the coastal area (Haas 1953); the much earlier record of *Hippopotamus* from the Pleistocene of Bethlehem (Gardner and Bate 1937) is erroneous, and probably based on a deceptive fragment of an *Archidiskodon* molar (Hooijer 1958). In 1953 Dr. Haas stated: "Hippopotamus remains of early to middle Paleolithic times have been dredged recently from the bottom of the bed of the upper Jordan south of the lake of Huleh", but I have not seen this material unless it is the teeth recorded above from Jisr Banat Yaqub, which, however, according to the accompanying label were excavated (in 1951), not dredged.

ORDER ARTIODACTYLA — FAMILY CERVIDAE

Dama cf. **mesopotamica** (Brooke)

A phalanx from layer B, found during the 1937 season, closely resembles the first phalanx of the 3rd digit of the left, or the 2nd digit of the right foot in *Dama dama* (L.), the European fallow deer; it is only slightly more extended anteroposteriorly at either end (see Table III). It is highly probable that it represents the Iranian fallow deer, *Dama mesopotamica* (Brooke), the fossil remains of which occur in great abundance at Mount Carmel, from the Upper Acheulean up into the Mesolithic (Natufian) (Bate 1937).

TABLE III

Measurements of first phalanx of 2nd or 3rd digit of foot of Dama (in mm)

	Dama dama Leiden Museum cat. b	cat. c	cat. d	*Dama* cf. *mesopotamica* Jisr Banat Yaqub
Length	40	41	42	42
Proximal width	15	15	15	15
Prox. ant. post. diam.	19	20	18	21
Distal width	13.5	14	13	13.5
Dist. ant. post. diam.	12	12	12	13

ORDER ARTIODACTYLA — FAMILY CERVIDAE

Cervus cf. **elaphus** L.

A radius, from the right side, collected in 1950 from an unstratified deposit, as well as a right astragalus (same history) compare well with the red deer, *Cervus elaphus* L. The fossil radius is slightly larger than that of a recent male (Leiden Museum, cat. a) but smaller than that of a subfossil male from the Netherlands (Leiden Museum, reg. no. 6958), whereas the astragalus belonged to a smaller individual, of the size of a recent female (Leiden Museum, reg. no. 1313). The measurements are given in Table IV. There is further a frontal fragment with the pedicle but not including the burr, likewise obtained from an unstratified deposit at Jisr Banat Yaqub, that may well have belonged to the same species as the bones mentioned.

TABLE IV

Measurements of bones of recent and fossil Cervus (in mm)

	Cervus elaphus Leiden Museum cat. a	no. 1313	no. 6958	*Cervus* cf. *elaphus* Jisr Banat Yaqub
Radius				
Median length	280	260	310	290
Proximal width	60	55	61	62
Distal width	56	48	57	53
Astragalus				
Lateral length	57	52	60	54
Distal width	36	33	38	35
Anteroposterior (medial side)	33	29	34	29

According to Azzaroli (1953) the red deer immigrated from Eastern Europe or from Asia during the Mindel-Riss Interglacial. The deposits of Mosbach and Mauer do contain *Cervus* species close to, but not identical with, *Cervus elaphus* (which appears in the Riss Glaciation); in the absence of antlers it seems best to identify the Jisr Banat Yaqub cervid as *Cervus* cf. *elaphus* L. The true *Cervus elaphus* is present in the Tayacian and the Upper Acheulean of Umm Qatafa, Israel (Vaufrey 1951), in the Lower Levalloiso-Mousterian up into the Upper Aurignacian of Mount Carmel (Bate 1937), and it still occurred in the Mesolithic (Natufian) of the Kebara Cave (Bate *loc. cit.*). *Cervus elaphus* is now extinct in this region.

ORDER ARTIODACTYLA — FAMILY BOVIDAE

cf. **Bison priscus** (Bojanus)

A fragment of a horn core excavated in 1951 at Jisr Banat Yaqub from the base of Bed V has a length of 23 cm, but the sinuses are exposed along the entire length. At no point is the external surface preserved all around, so that the shape of the cross section cannot be determined. The diameter at the proximal end of the fragment is about 9 cm, that at the distal end is about 5 cm. The core is curved without any apparent torsion (pl. IV figure 3); it can be matched precisely with a horn core of *Bison priscus* (Bojanus). It is, therefore, likely that it represents this species of bison, which is known from Süssenborn, Mosbach, Mauer, etc. There are further two isolated molars from an unstratified deposit at Jisr Banat Yaqub, an M^2 sin. and an M_3 dext., that may belong to *Bison priscus* too. The upper molar is slightly worn, and measures 35 mm anteroposteriorly and 19 mm transversely at the top; at the base it measures 25 mm both ways. The M_3, incomplete basally, is 40 mm in length, and $25\frac{1}{2}$ mm in width, exclusive of cement.

Large bovines that may represent either *Bos primigenius* Bojanus or *Bison priscus* have been recorded from the Wady el-Mughara caves as *Bos* sp. (Bate 1937); they range from the Upper Acheulean into the Mesolithic (Natufian). The Early Pleistocene record of *Bos* sp. from Bethlehem (Gardner and Bate 1937) proved to be a *Leptobos* (Hooijer 1958); the *Hemibos* recorded from Israel by Pilgrim (1941) is probably likewise Villafranchian. *Bison priscus* is a definitely post-Villafranchian form widely spread in Europe but originating in Asia; unlike *Bos primigenius* it does not appear to have emigrated to North Africa. The provisional record of *Bison priscus* at Jisr Banat Yaqub, if substantiated by more complete specimens, may be the most southerly of the species.

GENERAL DISCUSSION OF THE JISR BANAT YAQUB FAUNA

The fossil teeth and bones of mammals discovered in the deposits at Jisr Banat Yaqub belong to the following species:

Elephas trogontherii Pohlig
Equus cf. *caballus* L.
Dicerorhinus merckii (Jäger)
Sus cf. *scrofa* L.
Hippopotamus amphibius L.
Dama cf. *mesopotamica* (Brooke)
Cervus cf. *elaphus* L.
cf. *Bison priscus* (Bojanus)

Of these, the elephant is the most abundantly represented and at the same time the most significant element. As already related in the chapter on *Elephas trogontherii* the resemblance of the Jisr Banat Yaqub elephant to that of Süssenborn and Mosbach in Germany is so close that we cannot but conclude that the layers in which this elephant occurs are approximately contemporaneous with the 2nd Interglacial (Mindel-Riss) deposits of Europe. Neither would any of the other species found at Jisr Banat Yaqub be out of place in a fauna dating from the Great Interglacial. Although Merck's rhinoceros, the hippopotamus, and perhaps the caballine horse do occur in older Pleistocene deposits as well, the fauna as a whole is a typical interglacial or interpluvial fauna that may well be considered contemporaneous with the Second Interglacial. It should be borne in mind, however, that many of the specimens are without a record for the exact level at which they were found; we know only that some of the molars of *Elephas trogontherii* are from layers D up to and including B (1.10–0.42 m), that one horse tooth and the *Dama* phalanx are from layer B (0.60–0.42 m), and that one of the *Dicerorhinus* premolars came from layer C (0.92–0.60 m). Further the 1951 material, including *Elephas trogontherii, Dicerorhinus merckii, Hippopotamus amphibius,* and cf. *Bison priscus,* was obtained from the base of Bed V (3.40–2.50 m) (Dr. Stekelis, in letter, October 5, 1959). The Acheulean industry of Bed V has been briefly described by Stekelis (1956), who terms it Old Acheulean, the earliest Palaeolithic industry found in the Near East, but who does not give even a tentative dating. Picard (1952) placed the Jisr Banat Yaqub beds in the Lower Pleistocene (his Pluvial A, covering the Günz and the Mindel Glaciations), or in the transitional period between the Lower and the Middle Pleistocene (that is, the Interpluvial between the Mindel and the Riss: Picard *loc. cit.*). This last conclusion is the one with which I agree: the fossil mammals from Jisr Banat Yaqub indicate that the beds correspond approximately in time with those of the Mindel-Riss Interglacial.

As such, the Jisr Banat Yaqub fauna is definitely older than the oldest fauna found in the cave deposits of Mount Carmel, viz., in level F of Tabūn (Bate 1937), which has been assigned to the Last Interpluvial (Riss-Würm) by Zeuner and others. Level E of Tabūn contained a fragment of an elephant's tusk (Bate *loc. cit.*), which could give no indication as to what species it had belonged to. Likewise unidentifiable elephant remains have been recorded from a boring near Yavneh, Israel, by Avnimelech (1951); the level at which the *Elephas* was encountered is just above the marine Tyrrhenian transgression, and may represent early Würm.

The oldest elephant thus far found in Israel is the Early Pleistocene *Archidiskodon* cf. *planifrons* from Bethlehem (Hooijer 1958); it is associated with a characteristically Villafranchian fauna, and there can be no doubt that it should be assigned to the Early Pleistocene. It could be placed in the Günz, or in the Günz-Mindel Interglacial at the very latest. The Bethlehem *Archidiskodon* is an exceptionally primitive form of true elephant, lower-crowned than the earliest elephants of Europe. The evolutionary stage intermediate between *Archidiskodon* cf. *planifrons* of Bethlehem and *Elephas trogontherii* of Jisr Banat Yaqub would be *Archidiskodon meridionalis*

(Nesti), the presence of which in the lower layers of Jisr Banat Yaqub has in fact already been recorded by Stekelis (1956). In the collections reported upon in the present paper there is no evidence of the presence of an advanced archidiskodont elephant, however. Further collecting and accurate labelling of the specimens at Jisr Banat Yaqub will enhance the value of the site, which has already given us a Middle Pleistocene mammalian fauna unique in the Near East, filling to a large extent the gap that separates the Early Pleistocene Bethlehem fauna from the classic Upper Pleistocene Mount Carmel faunas of Israel.

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ADDENDUM

When the present paper was already in proof, I received from Professor G. Haas of the Hebrew University, Jerusalem, the molar fragment on the basis of which *Elephas meridionalis* had been included in the faunal list of Bed V of Jisr Banat Yaqub by Stekelis (1956). According to the accompanying label the specimen is from an unknown horizon but definitely from Jisr Banat Yaqub, and it had been identified by Dr. A. T. Hopwood as "a form more primitive than *Elephas meridionalis*". The examination of the actual specimen has convinced me that it represents *Stegodon*. The fragment, representing part of an upper left molar, is the first evidence of the presence of a stegodont in Israel. *Stegodon* is a Pliocene and Pleistocene genus of proboscideans occurring in southern and eastern Asia (from India, China, and Japan to Java, Flores, Celebes, and the Philippines), but it is also known from various parts of Africa (Cyrenaica, Kenya, Uganda, and the Cape). The newly discovered Israel *Stegodon* forms a link between these two areas of distribution, and will be fully described and discussed in a later paper.

THE PROPERTIES OF THE WAVES AT ISRAEL'S COAST

H. L. STRIEM

ABSTRACT

The report presented deals with the main characteristics of the waves arriving at Israel's shore.

The range and distribution of wave periods are shown to change little with the seasons, but there is a marked daily variation. The mean period is found to be related inversely to the wave height: the higher the waves the shorter is their mean period.

The analysis of wave heights shows a small daily variation but a large seasonal effect. Most striking is the qualitative difference between summer and the two winter seasons as regards the occurrence of very high waves — the mean winter wave energy is found to be several times greater than that of summer waves.

A short description of the duration of high states of sea is included because of their erosional effect.

It is found that the distribution of wave directions gives significant results only when considered for each wave height separately. The rule established is that the more northerly the direction the higher are the waves. The correlation with fetches is noted.

The most interesting result is that the total resultant wave direction has a component parallel and northward to our coast. The author's computation indicates a current velocity of about half a knot at least, and hence this almost permanent water movement due to wave incidence constitutes the main tributary effect to our northward longshore current.

The difference in the rates of veering is noted and the angle of lag between wind and wave directions is discussed.

INTRODUCTION

The aim of the author's study of the waves at Israel's coast was to find those quantitative and qualitative properties which are responsible directly or indirectly for the erosional processes at and off the shore.

This preliminary report however gives only such results of the analysis as may be presumed to be of a more general interest.

The data for the research were supplied through the courtesy of Israel's Meteorological Service, and are mostly in the form of lists of observations and partly in the form of statistical compilations.

The only consecutive observations of waves coming directly from the Mediterranea Sea were made at either Jaffa Port or at Tel-Aviv Port and extended over periods of four or five years at the time this report was prepared. The observations, especially of wave heights, were based on estimation rather than on measurements and furthermore they represent means for several waves. Thus statistics for but a few years allow of necessity only limited accuracy, and statistics for longer periods may well modify the figures arrived at. The author however believes that the general trends and orders of magnitude noted in this report reflect the characteristics of the waves arriving at Israel's shores.

GENERAL

1) The main cause for the sea waves arriving at our coast is the wind. Its strength, direction and the duration of its blowing are directly responsible for the wave properties.

Waves are generated and propagated both from nearby and from great distances, and a direct correlation between the properties of the waves and the wind as observed at the coast is not necessarily possible. Particularly important is the wind fetch, *i.e.* the distance of sea over which the wind was able to generate waves. build them up and keep them in existence.

2) At our shores the tide is of little importance. It rises and falls twice daily, but its usual range is only about 35 cm, its extreme values being about 60 cm. Thus the influence of the tide on the waves here is insignificant and it will not be further referred to.

3) Observations were taken of the following wave properties:
(a) the wave periods, *i.e.* the length of time which elapses between the passing of a fixed point by two successive wave crests.
(b) the wave heights, *i.e.* the difference in height between a wave crest and its trough.
(c) the wave directions, *i.e.* the direction of advance of broad wave fronts.

Observations were taken several times daily but during daytime only. The hours quoted in the text refer to the time of observation (GMT).

As noted above, the observations compiled were always means for several consecutive waves and did not refer to individual waves, thus eliminating to some extent unrepresentative fluctuations.

4) In the course of the analysis it became evident that for the purpose of generalisations regarding wave properties the months from May to September can be assumed as typical for summer conditions, and the designation "Summer" in the text refers to that period.

In accordance with the general climatic conditions a significant difference was found to exist between the period November–December and the period January–March, which are therefore designated in the text as "Winter I" and "Winter II" respectively, where the subdivision was necessary. The months April and October are intermediaries between the main periods.

Like the wind regime, the wave properties show a daily and a seasonal variation. The preponderence of either variation depends on the property considered.

5) Most wave properties arrived at or analysed further on are statistical abstractions, giving either means or the most probable values. These two latter abstractions do not, of course, necessarily coincide.

THE WAVE PERIODS

For a regular wave pattern approaching the shore the wave period may be considered as a primary and constant property of a wave. Near the shore the wave length and wave velocity are functions of the wave period and depth.

At our coast practically all wave periods occur between 4 sec and 15 sec. Periods of 3 sec are very rare. Genuine cases of periods larger than 15 sec are also seldom found, the observation of such long periods presumably included multiples of shorter periods of low waves which escaped notice.

The following table gives the distribution of periods in percentages of the total number of observed wave cases, for summer and winter and at the four times for which observations were available. In order to eliminate unrepresentative fluctuations the periods are given in groups of two seconds.

TABLE I

Frequency percentages of wave periods

Observation at	06 hrs			09 hrs			12 hrs			15 hrs		
Periods (sec)	Sum.	Wi. I	Wi. II	Sum.	Wi. I	Wi. II	Sum.	Wi. I	Wi. II	Sum.	Wi. I	Wi. II
$\leqslant 4$	5	5	8.5	9	6	8.5	5	6	10	2	4.5	6
5–6	28	28.5	31.5	33	27.5	34	35	28.5	37	44	38	41.5
7–8	30	27	28	27	33	30	38	39	29	34	37.5	33
9–10	28	22	16.5	19	21.5	12	12	20	13	13.5	18	11.5
11–12	5	6.5	6	3	8	7.5	3	4	5.5	5	1	6
13–15	4	7	5	6	2	3	6	1.5	3	2	0.5	2
> 15	0	3	4.5	3	2.5	5	1	0	2.5	0	0	1

Inspection of the table shows that about 85% of the periods observed fall into the 5–10 sec range.

Although the material available does not permit the establishment of a seasonal variation in the distribution of wave periods, it appears that in winter the periods are distributed over a slightly larger range.

The daily variation, however, is well marked: while in the morning the wave periods are distributed more evenly over their main range, with the advance of the day the majority of the periods concentrates into a narrowing range.

Thus the 5–8 sec range of periods includes (of all wave cases):

Season	% at 06 hrs	% at 15 hrs
Summer	58	78
Winter	57	76

The mean periods, as computed from the frequency of occurrence, are:

Season	Sec at 06 hrs	Sec at 15 hrs
Summer	7.8	7.2
Winter	7.3	7.0

The most frequent periods, as found from the frequency maximum, are:

Season	Sec at 06 hrs	Sec at 15 hrs
Summer	7–8	5–6
Winter	5–6	5–6

As regards the relationship between *wave period and wave height* the following important rule is found to hold:

The higher the waves, the shorter are their periods.

This finding corresponds to the empirical rule discovered long ago by Cornish whereby the wave steepness is inversely proportional to the wave period.

This rule can be found from the distribution curve of wave periods for different wave heights, where it is evident — at least within the range of observed waves — that the higher the waves the narrower is the range of their periods, favouring particularly the shorter periods. The rule is best exemplified, however, by comparison of the mean wave periods of the different groups of wave heights.

Thus, taking the means of afternoon observations, one finds:

Season	Size of wave (m)	Mean period (sec)
Summer	0.5	7.6
	1	6.5
	1.5	5.8
Winter	0.5	7.6
	1	7.0
	1.5	6.6
	2	6.4
	2.5	6.0

An oversimplified explanation for this correlation might be attempted as follows:

The greater the wind strength the higher and the faster are the waves which it generates. As a larger velocity means a shorter period, the higher waves have the shorter periods.

THE WAVE HEIGHTS

This chapter deals first with the analysis of wave heights and then considers the duration of a state of high sea.

The wave height depends on the strength of the wind which generates the waves, on the length of time of its blowing and on the fetch, *i.e.* the distance of sea over which the wind was able to generate waves, build them up and keep them in existence.

In accordance with the general observation that the wave height is proportional to the square root of the fetch, the author found this relationship to hold if low waves (which may have been caused by local winds, for example) are excluded.

Regarding wave heights marked quantitative and qualitative differences are found between summer and winter, but the daily variation is of lesser magnitude.

For a general survey it is practical to consider three groups:

a) calms

b) waves of medium height, *i.e.* waves up to and including 3/4 m height

c) waves of one metre and higher.

In the following the percentage figures refer to the total number of observations, unless otherwise stated.

a) *Calms*

The situation is best described by the numerical comparison of the percentage which the calms constitute:

Season	% at 06 hrs	% at 15 hrs
Summer	26	8
Winter	35	24

Thus while in summer the number of calms decreases greatly from morning to afternoon, in winter their number is considerably greater and the daily decrease is much less.

b) *Waves of medium height*

The whole group of low and medium waves constitutes the following percent of all observations:

Season	% at 06 hrs	% at 15 hrs
Summer	64	72
Winter	32	38

Thus one finds that in summer about two-thirds of all observations are waves of low or medium height. Taking into account also the cases of calms, this means that if any waves at all are observed, eight out of ten times a low sea will be running in summer. The seasonal variation is large, and in winter the medium waves consitute only one-third of the observations and are thus half their summer frequency.

The daily increase in the occurrence of medium waves has the same magnitude in both seasons, about 15%.

c) *Higher waves*

This group shows significant differences between the various seasons, hence the winter data are given separately for the periods November–December (Winter I)

and January–March (Winter II). Again the frequency of occurrence of waves of one metre height or higher is given as a percentage of the total number of observations:

Season	% at 06 hrs	% at 15 hrs
Summer	10	20
Winter I	23	26
Winter II	40	47

Thus also for higher waves the daily variation is of small magnitude, winter afternoons showing again an increase of about 15% over the morning values.

While the striking quantitative difference between summer and winter should be noted, the qualitative change between the seasons is of even greater significance.

Subdividing the wave group into waves of 1 and 1½ metres height and waves of two metres or more, the following frequency percentage (of all wave cases) are obtained:

Season	% for 1–1.5 m	% for 2 m or higher
Summer (June–August)	17.5	0.3
Winter I	16	9
Winter II	27	16

Thus in summer waves of two metres height or more occur only very rarely, in winter however they constitute more than one-third of the whole group of high waves.

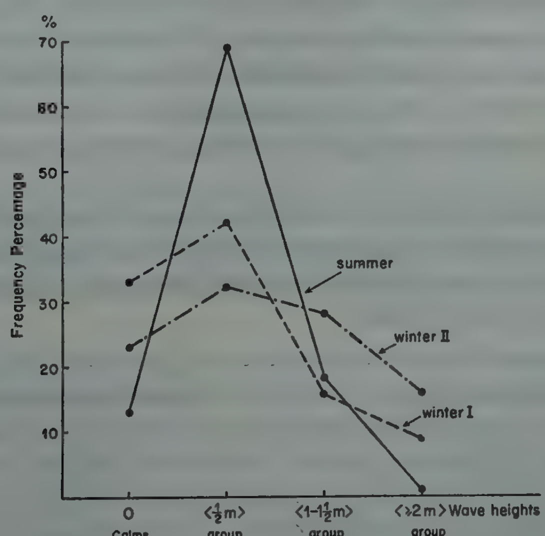

Figure 1
The seasonal variation of wave heights

In figure 1 the seasonal variations are illustrated and summarized for all wave heights.

As the daily variation is of secondary magnitude, the mean wave heights are indicative of the seasonal variation. Taking means for all observations, one finds:

Season	Mean wave height (cm)	Calms %
Summer	63	13
Winter I	95	33
Winter II	118	23

Computing mean wave heights for cases of wave observations only ,*i.e.* excluding calms, one finds:

Summer	Winter I	Winter II
72 cm	141 cm	154 cm

The fact that at our coast the energy of a mean winter wave is several times greater than that of a mean summer wave is of importance in structural and morphological considerations.

The duration of a high state of sea

It was interesting to examine the length of time during which the sea was running with waves of two metres height or more, hereinafter designated as a "high state of sea".

As the data collected pertain to daytime observations only, an extrapolation was necessary to obtain some durations. Despite the limitations incurred thereby, the general validity of the main trends noted further on appears dependable. The statistical material available related to four years only, and thus the percentage figures given below may later be modified and should be taken as orders of magnitude rather than precise figures.

A corrected frequency curve for durations shows several maxima and minima. These peaks appear unrelated to the time of observations. This justifies the collecting of durations in groups, using the minima as limits of range. In this way the following groups of durations were found:

Duration (hrs)	Approximate peak frequency (hrs)
1–10	5
11–28	18
29–41	36
42–54	48
55 and longer	60

The following Table gives the frequency percentage of each duration group in the various seasons.

TABLE II

The duration of a state of high sea

	1–10 hrs %	11–28 hrs %	29–41 hrs %	42–54 hrs %	⩾55 hrs %	Total percentage	Mean monthly percentage	Mean monthly duration hrs
May–September	4	6.5	—	—	—	10.5	2	11
October–December	12	4	←	7	→	23	8	12
January–March	9	27	12	← 10.5	→	58.5	18.5	24
April	1	7	—	—	—	8	8	17
Total	26	44.5	13.5	8	8	100		

In summer, as was to be expected, the months May–September account together only for one-eighth of the number of cases of high sea in winter. Furthermore, in contradistinction to the winter months, a state of high sea in summer does not last for longer than 28 hrs, *i.e.* it occurs within the first two groups.

While in April and in September the duration of a state of high sea belongs mainly to the second group, (11–28 hrs), the first two groups are equally favoured in the period May–July. For August no case of high sea was recorded.

In winter there are again notable differences between the first and the last months. The frequency of a state of high sea in the period October–December is less than half that number in the January–March period. During the period October–December the majority of cases occur in the first duration group (1–10 hrs), and in this period also appear the very long durations (4–8 days) connected with the occurrence of very heavy rain storms, so characteristic for this period of the year. On the other hand in the period January–March most cases occur in the second group (11–28 hrs) and none were recorded of a duration longer than three days.

WAVE DIRECTIONS

When the wind is rising, the waves that it generates run with it. Once in motion the waves maintain their original direction, which is defined as the direction of advance of wave fronts, *i.e.* perpendicular to the wave front. Winds from different quarters do not cause the waves to diverge from their direction although their wave height will be affected, and in the case of contrary winds the waves may be flattened out entirely.

Upon reaching shallow waters, *i.e.* a depth of about half a wave length or less, the waves are affected by the bottom configuration and are refracted when coming obliquely to the shore. This process of alignment is continuous and by the time the wave fronts become breakers at the shore they are practically parallel to it.

The observations of wave directions used in this report relate to a depth and a distance from the shore at which the process of refraction was not yet fully operative, and thus the wave directions were deemed to be representative of their original distribution.

The correlation: Wave heights — Wave directions

The data used for the consideration of wave directions referred to "states of sea",

designated by numbers, instead of wave heights in metres. The states of sea designated by numbers below three describe calms, rippled surfaces and smooth waves of about 30 cm high. Such low sea is mainly due to local and very slight winds, or to contrary winds flattening out oncoming waves. Their distribution is therefore quite irregular, and since these low ripples and wavelets are insignificant in their erosional effect, they are not further considered here.

The correlation between states of sea and wave heights will in this report be deemed as follows:

No. of state of sea	Approximate wave height (m)
3	0.6
4	1
5	1.7
6	2.3
7	3.1
8	4

In the course of the author's analysis it became apparent that the consideration of the frequency distribution of wave directions, when summed up for all wave heights, does not give significant results, and that the frequency distribution must be considered separately for each wave height.

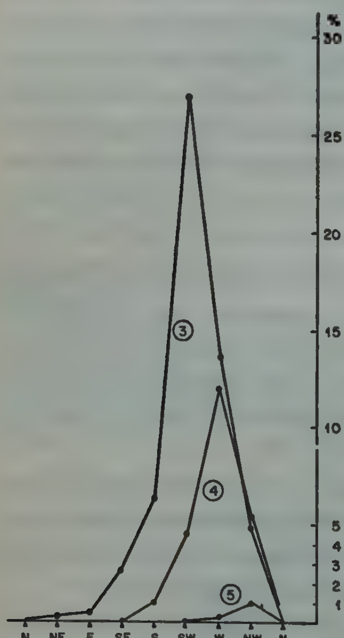

Figure 2
Swell direction frequencies and states of sea (encircled numbers) in summer

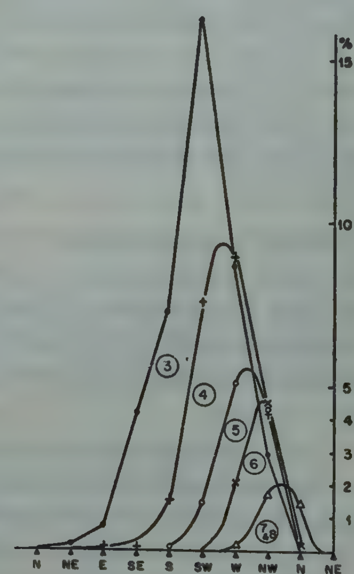

Figure 3
Swell direction frequencies and states of sea (encircled numbers) in winter II

As the graphs "Swell direction frequencies–States of sea" clearly show (Figures 2 and 3) the higher the waves the more northern is the direction from which they come.

The main reason for this rule lies in the geographical and meteorological situation of our coast:

(a) the storm centres at which high waves are generated lie mainly to the northwest and the north of our coast and

(b) the fetch, *i.e.* the effective distance of sea along which suitable winds may build up waves, is smaller towards the southwest and west (being bounded by the coast of Egypt and by meteorological conditions respectively), and longer towards the northwest. Indeed the author could establish a fair direct proportionality between the energy contents of waves and their respective fetches.

The seasonal resultant for wave directions

After the above description of the variations in wave heights and their correlation with wave directions, consideration will now be given to the distribution of directions as such.

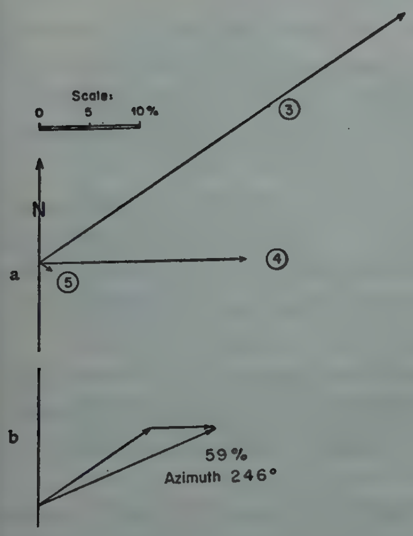

Figure 4
States of sea (encircled numbers) in summer
(a) Resultant swell directions
(b) Resultant direction of waves

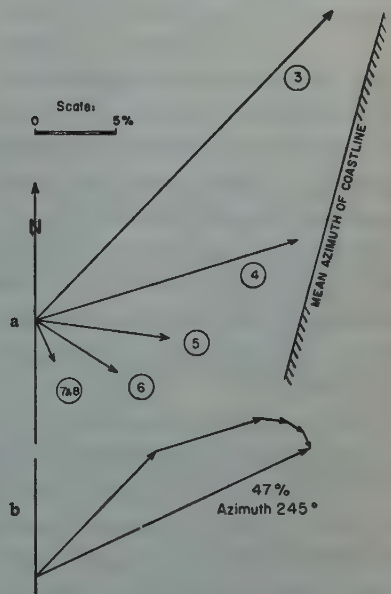

Figure 5
States of sea (encircled numbers) in winter II
(a) Resultant swell directions
(b) Resultant direction of waves

The diagrams given in Figures 4 and 5 give the means for the three daily observations, summed up for three months. Because the waves at night usually reduce much in height or die down altogether, the resultant wave directions are considered as representative. The diagrams give for summer and for winter II: (a) the resultant direction for each state of sea, and (b) the total resultant direction for each season.

A very interesting conclusion from these diagrams is that throughout the whole year, with the exception of the small number of cases of high waves from the northwest and north, the total resultant wave direction has a component parallel and northward to our coast.

This almost permanent water movement must be considered as a tributary effect to a northward longshore current.

A new formula given by Putnam, Munk and Traylor relates the velocity of the longshore current to the wave height, the wave period, the angle of approach and the slope of the beach.

Using the data given in this report for summer conditions, the author computed a longshore current of about half a knot to be produced by the waves.

As the various estimates and measurements taken so far indicate a current of about $\frac{1}{2}$–1 knot, the computed component due to wave incidence appears to account for most of the longshore current.

The daily variation in wave and wind directions

There exists an important difference between the frequency distributions of wave and wind directions: For winds the peaks of the frequency curves relate to almost the same direction for all wind strengths, whereas for waves, the peaks of the frequency curves have different directions for each wave height, being more northerly the higher the waves (Figures 2 and 3).

While both wind and wave directions depend on the strength and the position of their generating centres, the difference noted above is caused by the additional dependence of wave heights on the length of the fetch. For our coast the effective fetch is larger in the western direction, largest towards the northwest and least in the southwest.

One must also bear in mind that wave directions, once generated, are stable while wind directions are easily shifted by motion of the wind centre or by local conditions.

It follows that a correlation between wind and wave directions as observed at the coast is not necessarily possible.

During the day the wave directions veer in a clockwise sense, *i.e.* become more westerly and respectively more northerly. The magnitude of the daily veering decreases with the wave height, in summer it amounts to:

No. of state of sea	Degrees per hr
3	5.5
4	5
5	3.5

In winter the veering is less distinct and amounts to about 4 degrees per hour or less.

A comparison with the behaviour of the wind is quite instructive. Slight or moderate winds, up to Beaufort strength no. 4 inclusive, show in summer a regular veering from southwest (at 06.00 hrs) to northwest (at 18.00 hrs). Stronger winds veer less in magnitude and less distinctly: In winter I the southeasterly direction of wind in early morning changes towards noon into either a southwesterly or a northwesterly direction, in the first case without further veering and in the second case changing in the afternoon into a northerly wind. In winter II, winds of a strength of 3 Beaufort or more blow quite steadily from southwest or west without veering.

Thus in summer there is a difference in the rate of veering of wind and waves, amounting to about 2 degrees per hour, causing the waves to lag behind the wind. Hence, from 06.00 hrs, when both wind and wave directions coincide, there will come into existence an increasing angle between the directions of wind and of waves, as recorded at the shore, amounting to about 20 degrees at 16.00 hrs. As was explained above, this lag of the waves behind the wind must not be ascribed to the greater inertia of the waves, but to the different speeds of wind and waves and their generating centres.

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LETTER TO THE EDITOR

Ventifacts from Dimona (Kurnub) Sandstones, M. Avnimelech, *Department of Geology, The Hebrew University of Jerusalem.*

The Neogene — Upper Miocene to Lower Pliocene — sandstone formation of the central and east-central Negev, extending from Kefar Yerukham (Rekhme) to Dimona (Kurnub) and still farther to the east, constitutes part of the Hosb (or Hasb) series[1,2] of the "undivided Neogene–Quaternary"[2]. This formation very often contains flint pebbles, arranged in thin, nest-like, discontinuous assemblages. These pebbles are well exposed in several places, as for instance near the crossroads in the vicinity of the new urban settlement of Dimona. The pebble-bearing sandstone is very friable, rusty-brown,

Figure 1

Neogene ventifacts from Dimona (Kurnub), showing different, but generally poor, grades of rounding.

Received June 1, 1959

limonitic and clayey. The sand grains are medium sized, not well sorted, generally not well rounded, uncoated and of brilliant lustre. This seems to indicate that the sands were originally deposited in the sea and were under aeolian influence for only a short time. This is corroborated by the fact that only 10 km to the west similar sands contain big shells of *Crassostrea*.

The pebbles are mostly of Campanian and few of them of Lower Eocene flint. They are mostly unsorted (Figure 1), their sizes being very variable and attaining up to 10 cm diameter; their degree of rounding is very poor, not one of them attaining spherical or oval shape and there are no flattened pebbles. The smaller pebbles are mostly non-rounded or rounded from one side only, thus indicating that they are fragments of former bigger and rounded pebbles. All pebbles reveal well

Figure 2
Pebbles-horizon contorted by sand-creeping (drawn from photograph).

leveloped patina, the patina of the bigger pebbles being thick and almost black, while that of the maller ones is brown. The dark patina results from longer and more intense insolation; thus t must be older than the brown one.

Almost all of the pebbles show patches of desert varnish: their tint is dark maroon.

These characteristics allow us to reconstruct the following sequence of events in the Dimona Kurnub) area during the Middle Neogene (Upper Miocene–Lower Pliocene) times:

a) The pebbles resulted from erosion of exposed Senonian and Eocene stratas by seasonal rainfalls nd short occasional streams. The conditions were of a semi-desert climate. The broad, faulted, ynclinal valleys were already filled with sands which had drifted from the nearby seashores. In some laces oases or woods had existed, as witnessed by silicified trunks, which I had encountered for the rst time on a reconnaissance trip 13 years ago.

b) Later, the climatic conditions became more arid so that the oases gradually disappeared. The intense insolation produced the dark patina on the exposed pebbles. In the meantime, the dead tree trunks were covered by drifting sand and under this cover they became impregnated by silica solutions and changed into silicified wood.

c) The withdrawal of the sea from Yerukham–Beersheba plains increased the aeolian action. Big dunes were formed, the relics of which are still visible in several areas of the central Negev. This sand movement naturally led to many unbalanced accumulations, causing sand-creeping well manifested by the contortion of the pebbles-horizon as seen in Figure 2 (drawn from photograph). Under these arid, aeolian conditions, desert varnish covered parts of the pebbles. The desert climate, with its extreme changes of tempera ture from day to night, caused the splitting of the bigger pebbles exposed on the surface into smaller ones, so that they remained unrounded and the patina on their freshly broken surfaces could not attain the deep black tint.

These phenomena were most probably not limited to the Dimona area alone, and there is evidence of their existence in other regions of the country. It seems that the siliciffied trees, well-known from the Neogene of Egypt, are connected in time and origin with similar regional conditions.

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ISRAEL GEOLOGICAL SOCIETY

Proceedings of symposium on epigenetic processes in carbonate rocks

Jerusalem. May 20 and June 10, 1959

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The influence of physical properties on the weathering processes of calcareous rocks

M. Ben-Yair, *The Standards Institution of Israel*

Physical weathering of rocks results in the fragmentation of a compact block into small particles, enhancing thereby chemical leaching. In the mountainous regions of Israel, fissures and cracks are found in hard calcareous rocks which were formed by physical weathering and then broadened by the action of water containing carbon dioxide or other acids.

Physical weathering is due to a number of factors. While the weathering process depends on external factors which are not connected with the rock itself, the rate of their activity is directly linked to the rock's internal structure and is evident in the physical properties of the rock.

Two main types of calcareous rocks are found in Israel, each posessing different physical properties.

1. *Hard rocks*, e.g. lithographic limestone, dolomite, marble, meleke (macrocrystalline limestone), *etc.*

2. *Soft and medium hard rocks, e.g.* chalk, marly chalk, marl, kurkar (calcareous sandstone), *etc.*

Determinations of porosity, mechanical properties, water movement by infiltration, capillary rise, evaporation and thermal properties of the different calcareous rocks indicate that outstanding differences exist between the properties of the soft and hard calcareous rocks. The influence of these properties on weathering activity is considerable, and the differences in the weathering products of the soft and hard calcareous rocks can be explained from the above conclusions. While the weathering residue from hard rocks is poor in lime, the residue from soft rocks is rich in lime, containing between 30% to 70% of calcium carbonate.

The calcareous rocks of Israel, which cover large areas in the mountainous region, are important raw materials in the chemical industry, building and agriculture. It is advisable to promote the study of their properties in the same way as other industrial minerals are studied in this country.

Dynamics of limestone solution and its application in the interpretation of geological processes

Dan H. Yaalon, *The Hebrew University of Jerusalem*

By dynamics of limestone solution we understand the totality of reactions and

movements that are continuously taking place in the $CaCO_3$ system under the influence of the environmental forces acting upon it.

The solubility relationships of $CaCO_3$ in limestone or in other calcareous rocks in nature are not different from that of pure calcium carbonate when studied in the laboratory. From these studies it is known that the major factors affecting the solubility of $CaCO_3$ are CO_2 pressure, pH and ionic strength (concentration of soluble salts and common ions) of the solvent solution, while the rate of solvent exchange is of greatest importance in controlling the rate of solution. For each temperature there exists an overall equilibrium condition, which is governed by at least five participating partial equilibria. Quantitative data of limestone solubility under various environmental conditions can be obtained by considering the interaction of these separate equilibrium states.

Evidence of limestone solution in nature by waters constantly or periodically undersaturated with calcium carbonate are the caverns, sinkholes and other irregularities of a karst landscape, the development of underground limestone aquifers, overhanging sea-level nips, and shallow tidal solution basins in coastal limestones. Solution of limestone and metasomatic volume by volume replacement at low temperature and pressure by mineralized ground-waters is responsible for the formation of epigenetic dolomites, which are locally important as oil or water reservoirs. A special case of partial limestone solution and recrystallization under semiarid conditions is Naritization, forming a crust-like layer capping porous limestones and marls. Solution and local reprecipitation of calcium carbonate causes the consolidation of calcareous dunes into the Kurkar beach rock. Differential solution and leaching of calcium carbonate, accompanied by certain alteration processes of the silicate minerals, takes place during surface weathering of limestones and the subsequent development of calcareous soils, such as Rendzina and Terra rossa. Though complex, the nature of these different natural processes can be elucidated from the considerations of the principles of limestone solution and its behaviour under the influence of all the interrelated factors.

The rate of weathering and denudation of a limestone area depends upon the volume of precipitation and upon its capacity to dissolve limestone. From data of average rainfall and runoff conditions of the Mediterranean climate and the average calcium content of ground water we estimate the rate of denudation by solvent action to be about 10 microns annually. For humid temperate climates the rate is 2 to 4x higher.

The total average erosion in the central parts of Israel since the emergence of the land some 35 million years ago, and assuming from stratigraphic analysis that a layer of about 300 to 350 m of mostly calcareous Eocene, Senonian and Turonian rocks have been removed by erosion, is of a similar magnitude, or about 10 mm per 1000 years.

The development of nari*

A. A. GOLDBERG, *Ein Harod*

In the mediterranean region of Palestine many permeable calcareous rocks develop a weathered surface crust known as *nari*, which is sometimes capped by a hard compact secondary crust.

Observations in thin sections and measurements of density and percolation indicate that compared to the underlying bedrock the nari is more porous, its crystals are larger and more interwoven. The hard secondary crust is non-porous and its particles largely recrystallized and cemented .The thickness of the nari crust is directly related to the permeability of the underlying base rock.

Results from chemical analyses show that when going from the base rock upwards, the clay content, *i.e.* the insoluble residue, first decreases and then again increases in the secondary compact crust; the percentage of carbonates increases in the nari but again decreases in the compact crust. The nari, while having a characteristic structure, lacks a typical chemical composition.

The research proves that nari develops by alteration within the rock itself, by terrestrial weathering under conditions of a mediterranean climate. During the winter there prevails dissolution by percolating rain water, in summer there is precipitation from water raising through capillary forces. Cool winter water dissolves the carbonates in the larger pores, while from the warm summer water clay is flocculated at the surface and the carbonates just below. The precipitation takes place in the small pores, while solution continues to act in the large pores. As a result of the cyclic solution–precipitation processes the surface is enriched in clay, its pores are being filled and the particles cemented resulting in the compact crust being formed. Below it the rock becomes enriched on carbonates, its porosity increases and its crystals become enlarged and interwoven — the nari has been formed.

The same weathering cycle, when acting on non-permeable rocks or when leaching prevails, gives rise to the formation of terra rossa soil and in fissured rocks to karstic phenomena. Thus the distribution of nari and terra rossa or karst are mutually restrictive.

Porosity characteristics of carbonate rocks in Israel

S. MANDEL, *Tahal — Water Planning for Israel*

Total porosity of sedimentary rocks reaches 30% to 40% of their volume. A considerable part of this porosity is composed of capillary pores, which do not enable free movement of ground water. From the hydrologic point only pores with an average diameter larger than 0.1 mm are significant and comprise the "effective porosity".

* Based on the author's Ph.D. thesis at The Hebrew University of Jerusalem, 1958.

Values of effective porosity vary from 1% in Turonian limestone of the southern Carmel, 3% to 5% in the dolomitic Turonian-Cenomanian aquifer of Western Galilee, and up to 12% in the Turonian-Cenomanian aquifer of the Lod foothills. However, the pore volume does not evaluate sufficiently all the porosity characteristics, and it is also necessary to know the pattern of the pores and the pore size distribution. An effective method to test the porosity characteristics is the pumping test. From these and other tests the following results were obtained so far.

Dependence of porosity on lithology. Generally only hard rocks exhibit a high effective porosity. This is due to fractures and fissures, and their enlargement by dissolution. Among the hard rocks limestones usually show clear signs of karstic features (*e.g.* the Turonian borings at Lod, and Ramon 1 in Western Galilee). Dolomitic rocks often develop a homogeneous porosity as a result of selective dissolution, which eventually alters the rocks into "dolomitic sand", as found in a number of borings at Kfar Uriya and Beersheva. An example of increased porosity through dissolution of hard rock is found in the Turonian-Upper Cenomanian aquifer in the region Wadi Keziv — Kabri in the Western Galilee.

Decreased porosity with depth. Theoretically it would be expected that because of pressure porosity will decrease with depth. However, this assumption is not confirmed from borings in carbonate rocks. Highly porous rocks are found at the depth of 800 m (Taanach boring), and oil well borings (at Zikhron Yaaqov, Motza and Tiberias) encountered very porous dolomite and even caverns at depths of 1000 m and more.

Development of solution channels along bedding planes. It is well known that borings in tilted beds usually have to be drilled to a greater depth before achieving the expected yields of water (borings of Kfar Uriya compared to borings of Hartuv). Such evidence supports the assumption that groundwater flows largely in solution channels along bedding planes.

Porosity in relation to tectonics, especially faulting. In theory the intensive fracturing in fault zones should increase the effective porosity and result in good hydraulic conduction. Practical experience does not entirely confirm this assumption. High hydraulic conductivity was found in borings near faults (Acre, Yagur, Shimron), but also distant from faults (Wadi Ara 2, Wadi Falah, Damon 1, Lod 20, *etc.*). Several borings in faulted zones gave disappointing results or showed only an average conduction (Shlomi, Tel-Adashim). On the other hand experience shows that regional karstic features and the development of high porosity is influenced mainly by the older fold structures, especially anticlinal promontories.

Diagenetic processes in carbonate rocks as inferred from the geochemistry of groundwater in Israel

S. Loewengart, *Haifa*

The observations reported here are based on the evaluation of numerous groundwater

analyses obtained from Tahal and on published data from Israel and from abroad.

The waters of the karstic aquifer of northern Israel contain a relatively high amount of HCO_3, while the SO_4/Cl ratio is similar to that of sea water. When the calculated contribution of sea water salts is subtracted, it is found that in the terrestrially derived solutes the ratio Mg/Ca increases with increasing salinity. When the ratio through the influence of sea water exceeds one, at a total salinity of about 500 to 600 ppm, magnesium is exchanged for calcium from the solid phase, resulting in *dolomitization.* In more concentrated solutions Mg is increasingly exchanged for Ca in the solid phase and very saline waters of marine origin reach a Ca/Mg ratio of about 2. The process of dolomitization has presumably taken place during the emergence of the sediments from the sea.

The above process is retarded or even reversed by the presence of sedimentary or residual gypsum. The high concentration of dissolved Ca from $CaSO_4$ may lead to the exchange of Ca for Mg from dolomite, causing *dedolomitization.* This is evidenced by the high concentration of magnesium in sulphate-rich waters.

On the occurrence of dolomitization in sedimentary rocks of Israel

Y. BENTOR, *The Hebrew University of Jerusalem*

Solution basins in Kurkar near Natanya

E. MAZOR, *Israel Atomic Energy Commission*

Some remarks on solution processes along the cliff coast of Israe

I. SCHATTNER, *The Hebrew University of Jerusalem*

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